Tau Neutrino Optimization for LBNE/DUNE

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Optimize nu-tau appearance in referenceGeometry

- Coded a probability function that a muon neutrino will oscillate into a tau neutrino, which took in four parameters from the equation

$$P_{\alpha\to\beta,\alpha\neq\beta} = \sin^2(2\theta)\sin^2\left(1.27\frac{\Delta m^2 L}{E}\frac{[\mathrm{eV}^2]\,[\mathrm{km}]}{[\mathrm{GeV}]}\right).$$

- Where alpha is nu-mu, beta is nu-tau, $\theta = \theta_{23}$, and $\Delta m^2 = \Delta m^2_{32}$

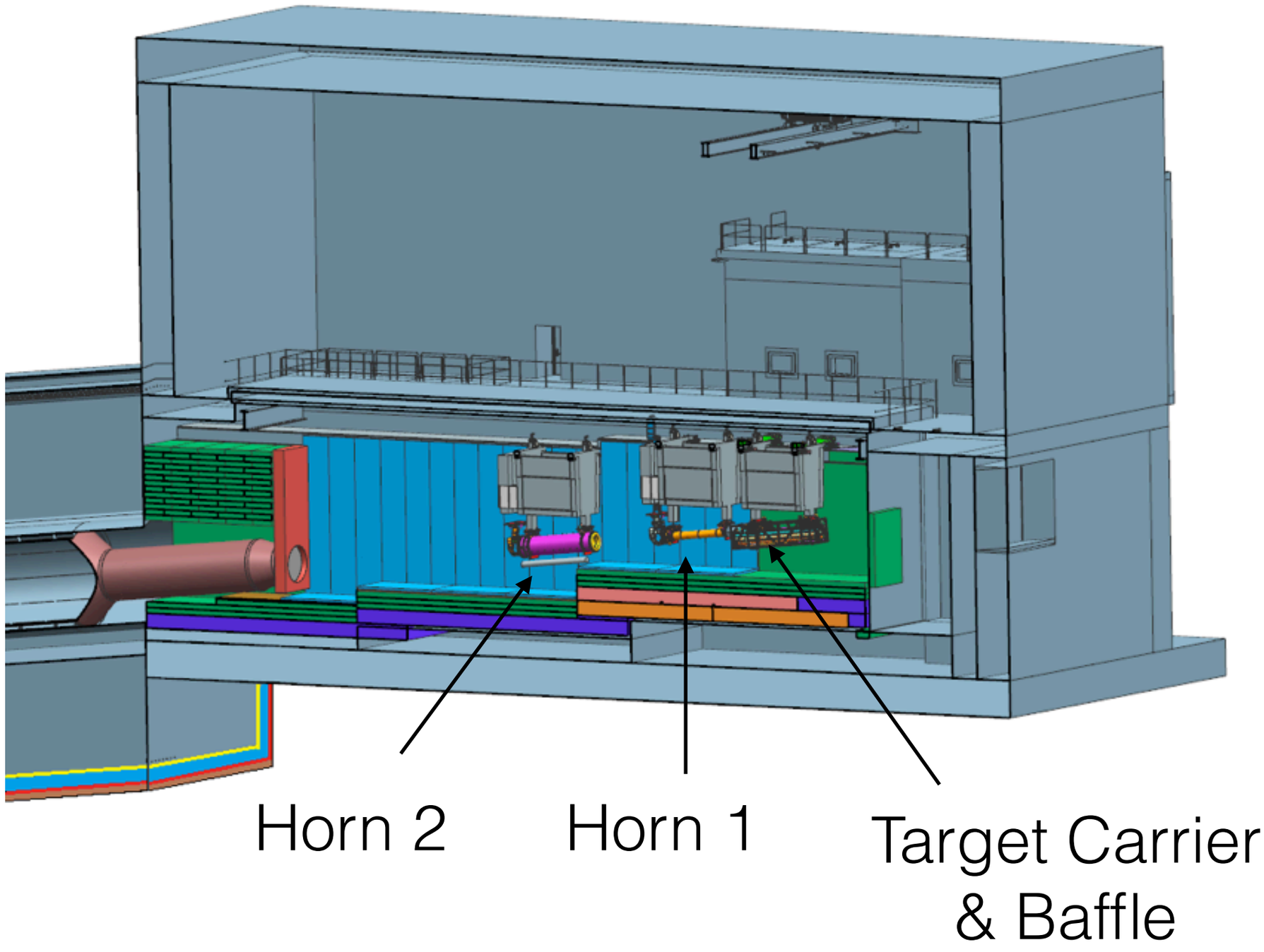
- The PDG values for normal hierarchy were used ($\sin^2(2\theta_{23})) = 0.999$, $\Delta m^2_{32} = (m_3)^2 - (m_2)^2 = 2.44\text{e-}03\ \mathrm{eV}^2$).

- The first and second mass states are similar in mass compared to the third, so we use the approximation $\Delta m^2_{32} = \Delta m^2_{31} = 2.44\text{e-}03\ \mathrm{eV}^2$.

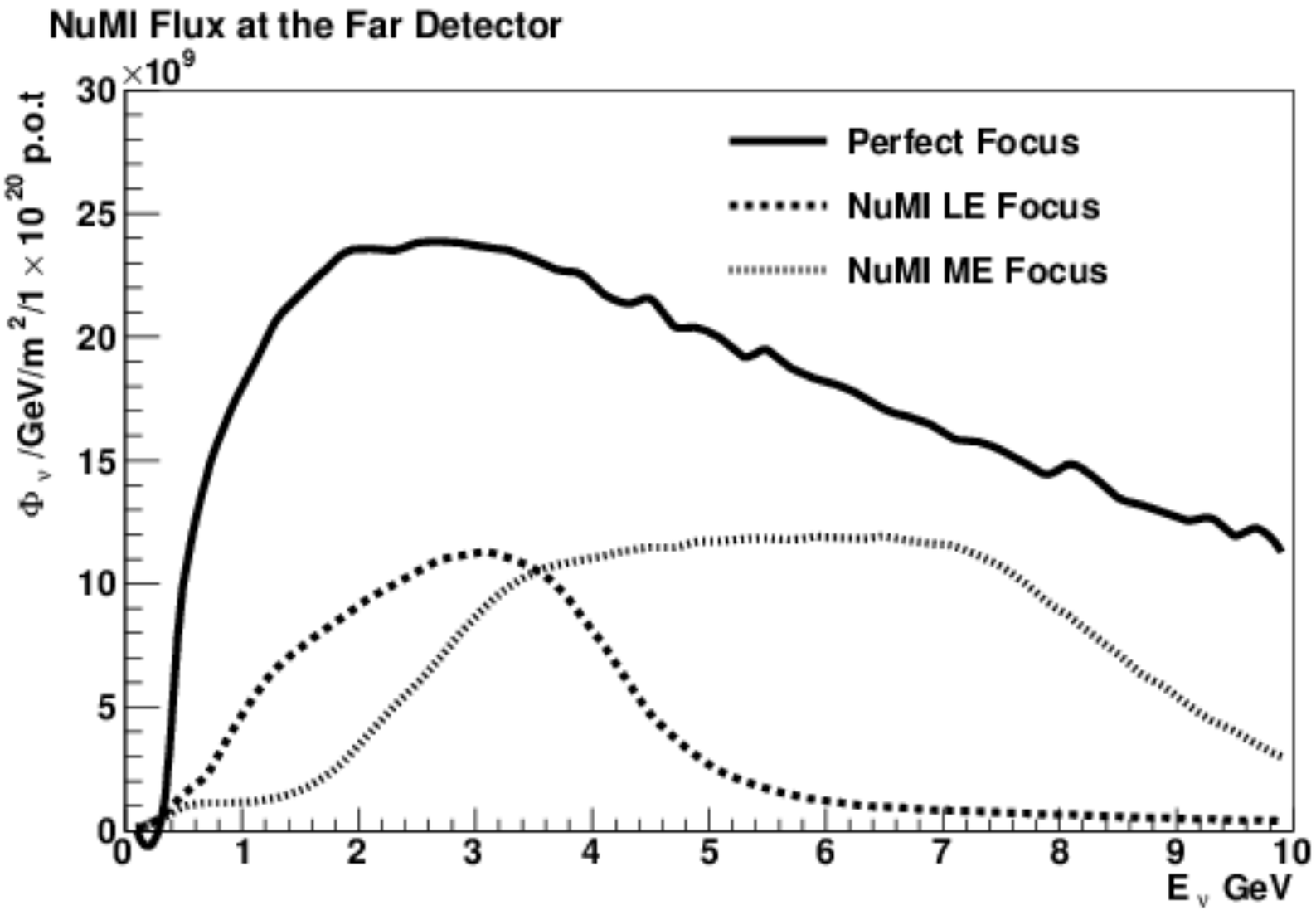
- The neutrino cross sections were read from a GLoBES data file, and neutrino cross-section/energy was plotted and a function was fitted.

- Function fitted up until 120 GeV, or the power of the beam.

DUNE reference design with NuMI style horns

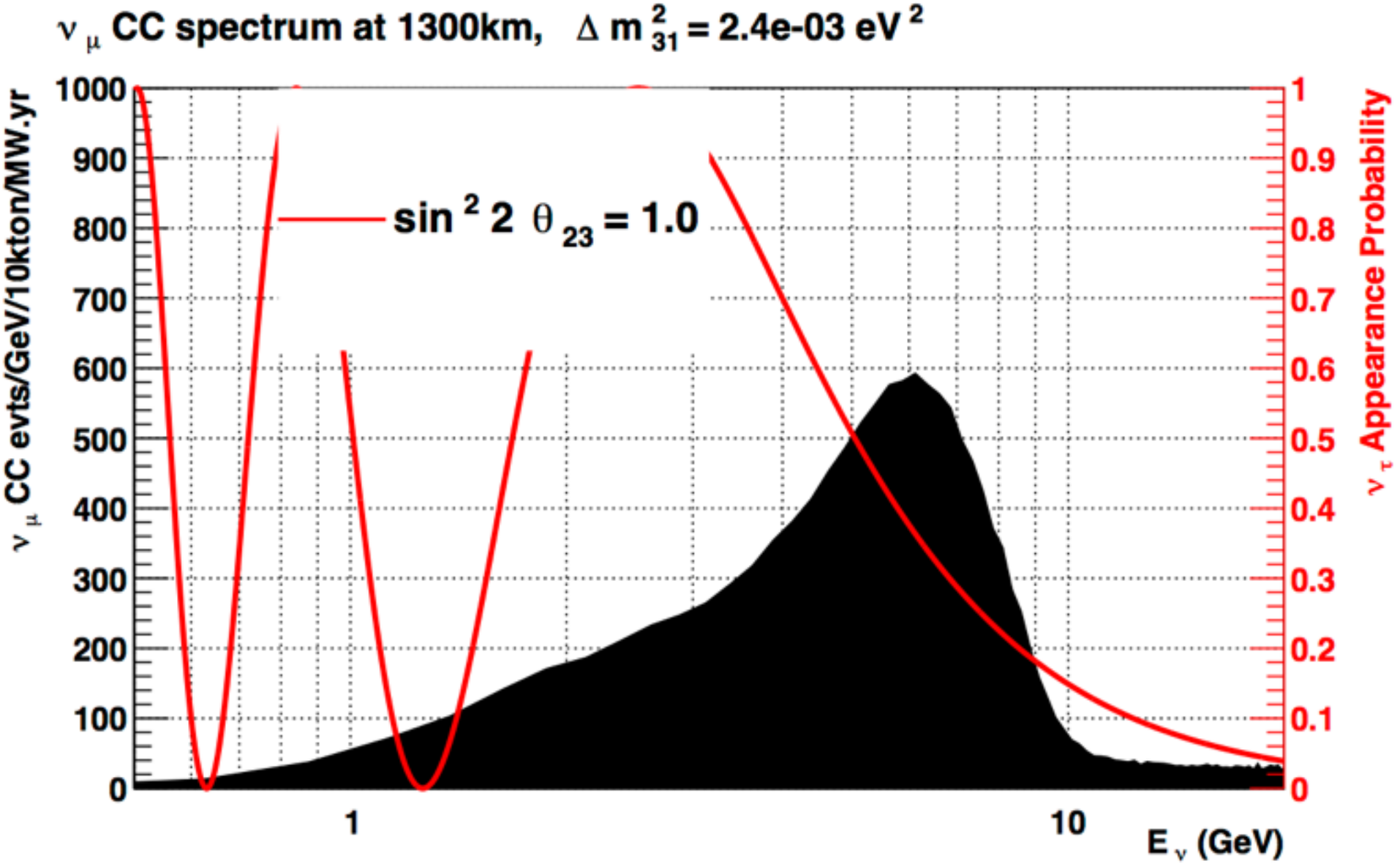


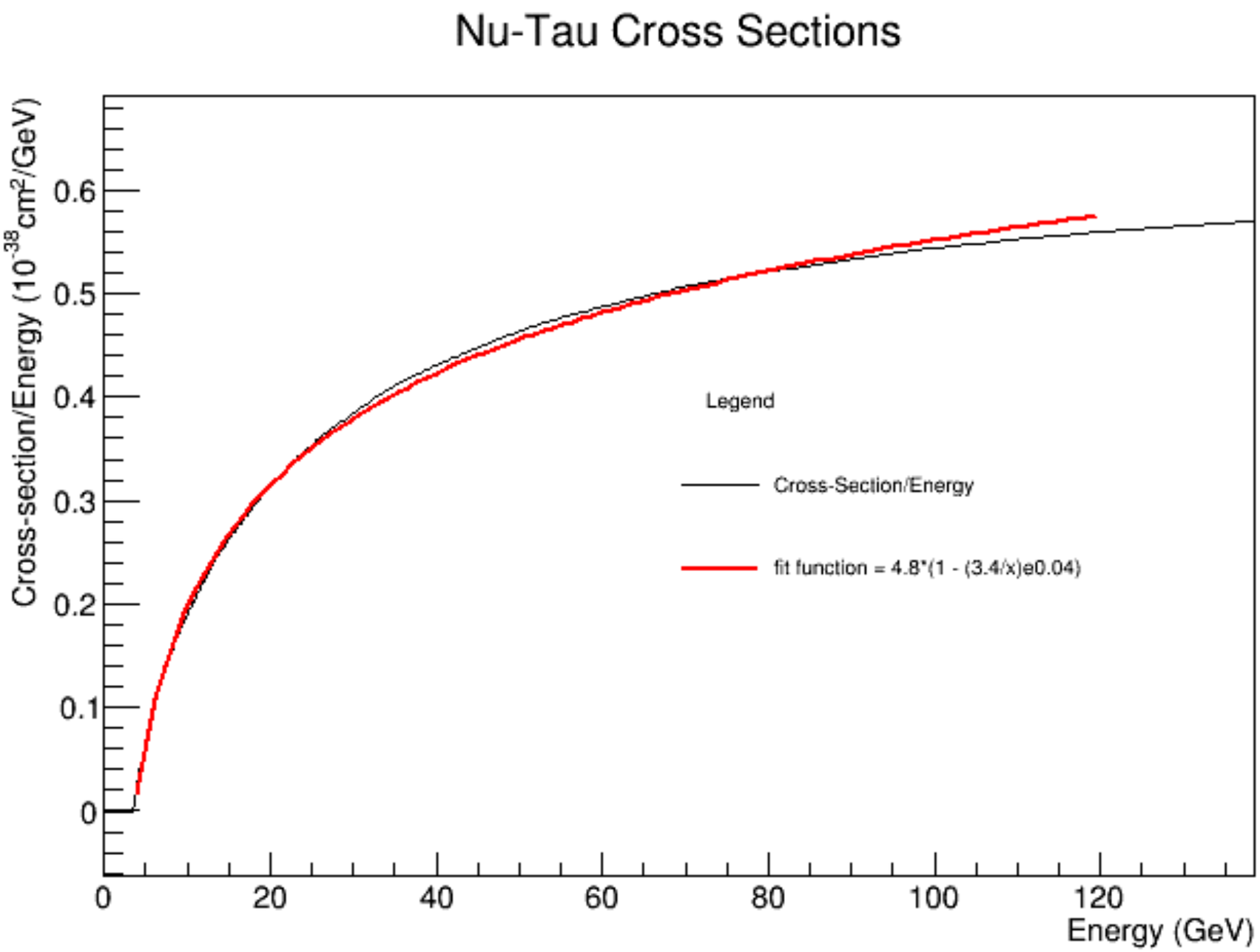
From "LBNF/DUNE CDR Volume 3: The Long-Baseline Neutrino Facility for DUNE"



P. Adamson et al., "The NuMI Neutrino Beam" Nucl.Instrum.Meth. A806 (2016) 279-306

Nu-tau probability appearance overlaid with unoscillated nu-mu spectrum at DUNE




Nu-Tau Cross Sections
Cross-section/Energy (10^{-38}cm^2/GeV)
0.6
0.5
0.4
0.3
0.2
0.1
0
0
20
40
60
80
100
120
Energy (GeV)
Legend
Cross-Section/Energy
fit function = 4.8*(1 - (3.4/x)e0.04)

- The target distance was moved upstream to 1.5m from Horn 1 compared to original 47cm. New location is 0.5m from the beam.

- The parameter tested was the location of Horn 2.

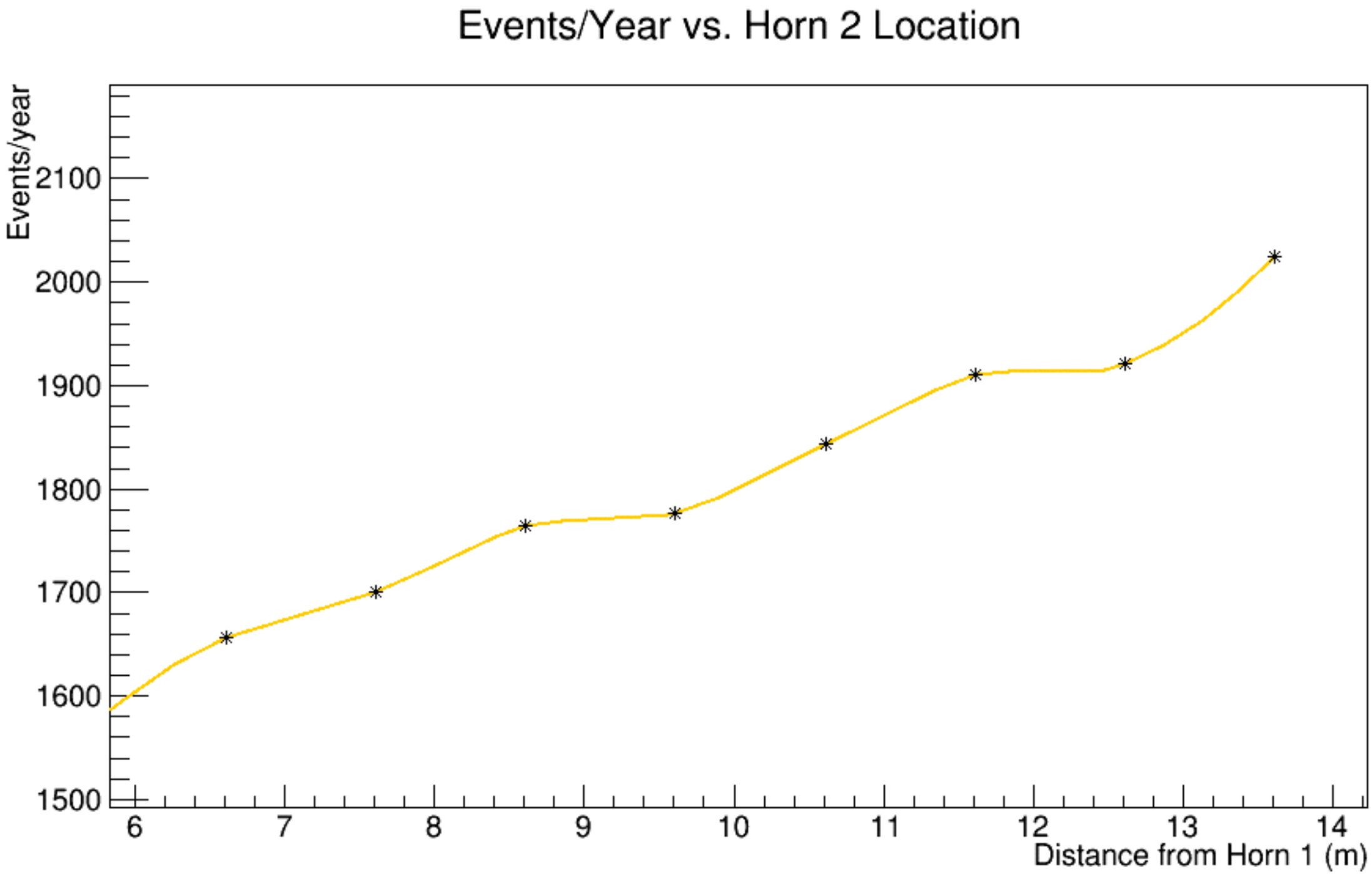
- Ran simulations moving Horn 2 downstream 7 meters in 1 meter increments.

- The flux, probability function, and neutrino cross section function (multiplied by neutrino energy) were multiplied together and plotted against the neutrino energy (GeV).

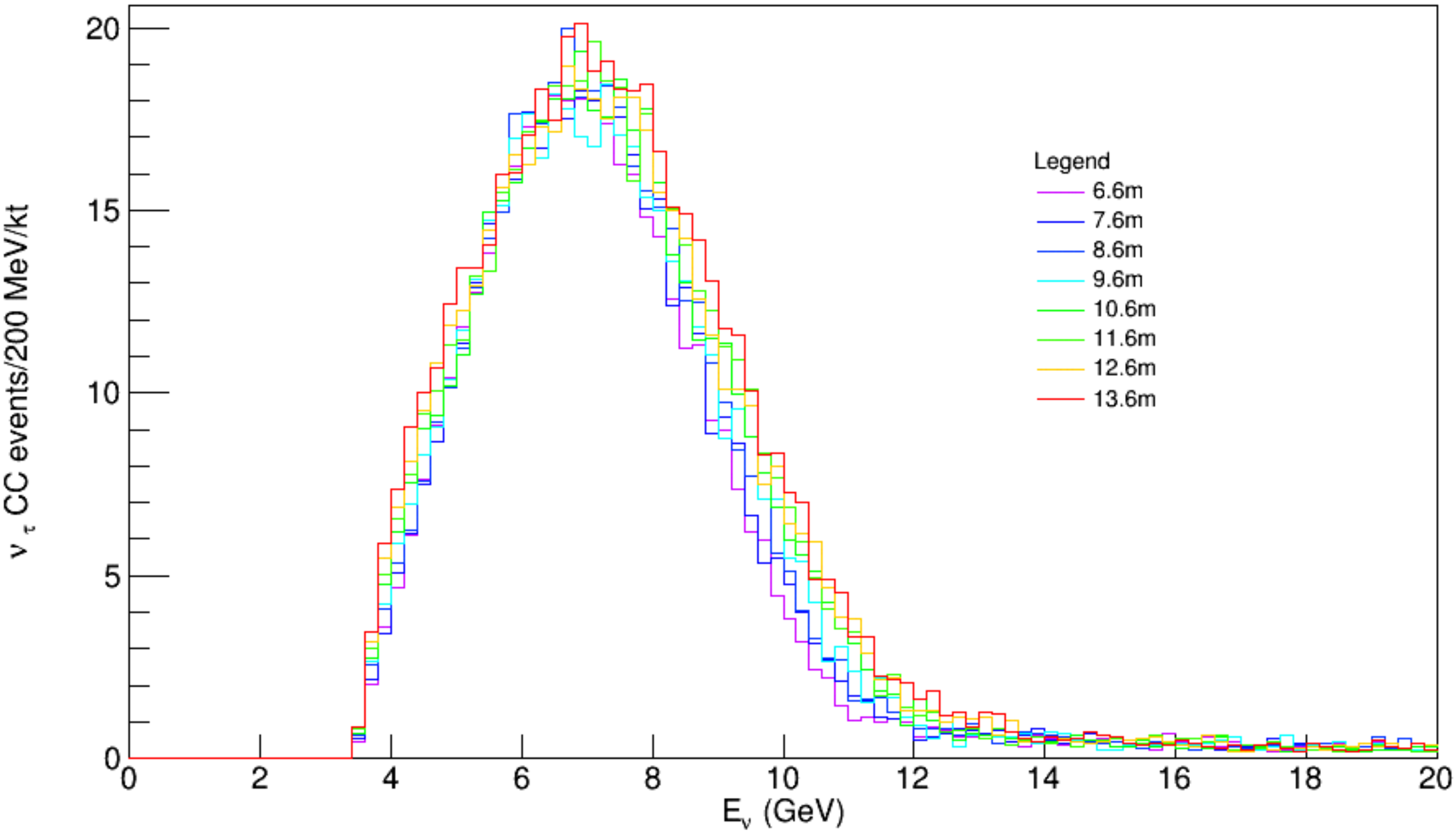
- Total number of events computed assuming 1e21 POT and a 40 kt detector.

Target Length: 1m
Target Distance to Horn 1: 1.5m
End of Tunnel: 17.485m
Length of Horn 2: 3.626m

Horn 2 Distance from Horn 1 (m)	Rate (events/yr)
6.6110	1657
7.6110	1700
8.6110	1764
9.6110	1777
10.6110	1844
11.6110	1910
12.6110	1921
13.6110	2025


Events/Year vs. Horn 2 Location
Events/year
2100
2000
1900
1800
1700
1600
1500
6
7
8
9
10
11
12
13
14
Distance from Horn 1 (m)

Cross-Section Overlay of Horn 2 Moved Downstream



To-do list

- Compare the events of a target length of 1m to target length of 2m both in referenceGeometry design.

- Compare the referenceGeometry (two horns) to the optimizedGeometry (three horns) moving horn 3 at 1 meter increments.